Memorandum for: Calibration Product Oversight Panel (CalPOP)

From: Michael Grotenhuis, ERT at NOAA
Xiangqian Wu, NOAA/NESDIS
Fangfang Yu, ERT at NOAA

Subject: Improvement to GOES Imager Visible Channel Operational Calibration Algorithm to Prevent Decreasing Correction Coefficient Anomalies

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Summary

There are times, especially in the early operational period, when the GOES Imager Visible Channel Operational Calibration algorithm exhibits an anomalous behavior where the correction coefficient decreases from one month to the next. Superficially, this would seem to indicate that the instrument degradation has reversed, when in reality the behavior is due to uncertainty inherent to the Operational Calibration data and methodology. To prevent confusion, it is proposed that when the Operational Calibration algorithm produces a correction coefficient that is smaller than the previous month's, the previous month's coefficient is published instead.

Introduction

The visible channel of the operational GOES Imagers is calibrated using co-located Moderate Resolution Imaging Spectroradiometer (MODIS) measurements (Wu & Sun, 2005). The MODIS measurements are regarded as truth data, as MODIS is radiometrically well-calibrated due to an advanced onboard calibration system. The methodology produces correction factors, adding approximately 3 to 5 collocated cases every month, by which the GOES Imager Visible Channel radiance data should be multiplied to match that of MODIS for that particular day.

To provide timely Operational Calibration updates, all the accumulated correction factors for a satellite are regression-fit to an exponential. The next month's GOES Imager Visible Channel Operational Calibration coefficient is extrapolated from the exponential. Because the GOES Imager Visible Channel experiences continuous degradation on-orbit, one would expect the GOES Imager Visible Channel Operational Calibration coefficients to increase every month, given a perfect Operational Calibration methodology and input data.

However, especially early in the operational lifetime of a GOES Imager, the uncertainty of the Operational Calibration is relatively high. In this period, the addition of another month's correction factors may cause large variations in the new regression parameters. Sometimes, the new result of an Operation Calibration coefficient may be smaller than the coefficient from the previous month. A GOES user might be confused by such behavior, as it would seem to indicate that the GOES Imager visible channel degradation had reversed.

To prevent confusion, it is proposed that, in those anomalous instances in which the GOES Imager Visible Channel Operational Calibration produces a smaller coefficient than that of the previous month, the previous month's coefficient is published instead. It is expected that this modification will continue to produce coefficients within the estimated uncertainty of the Operational Calibration.

Data and Analysis

The proposed improvement to the GOES Imager Visible Channel Operational Calibration algorithm is driven by an anomaly with GOES-15 where the current algorithm produced a calibration coefficient of 1.213 for the February 2012 update that is smaller than the January 2012 coefficient of 1.225. The GOES-15 satellite is in its early period of operation and the decreasing coefficient anomaly is a result of high uncertainty causing large fluctuations in the regression-fit to the exponential function. Figure 1 shows the data, trend line, and regression-fit coefficients used for the January 2012 update and February 2012 update. The uncertainty for the GOES Imager Visible Channel Operational Calibration is estimated via the standard deviation of the data points to the trend line. This estimation yields an uncertainty of 2.44% for the February 2012 update, and the decrease in the calibration coefficient from January to February is well within this uncertainty. Therefore, publishing the January coefficient for the February update as well provides a coefficient that is within the uncertainty of the Operation Calibration. For a discussion on the Operational Calibration uncertainty, please see the Appendix.

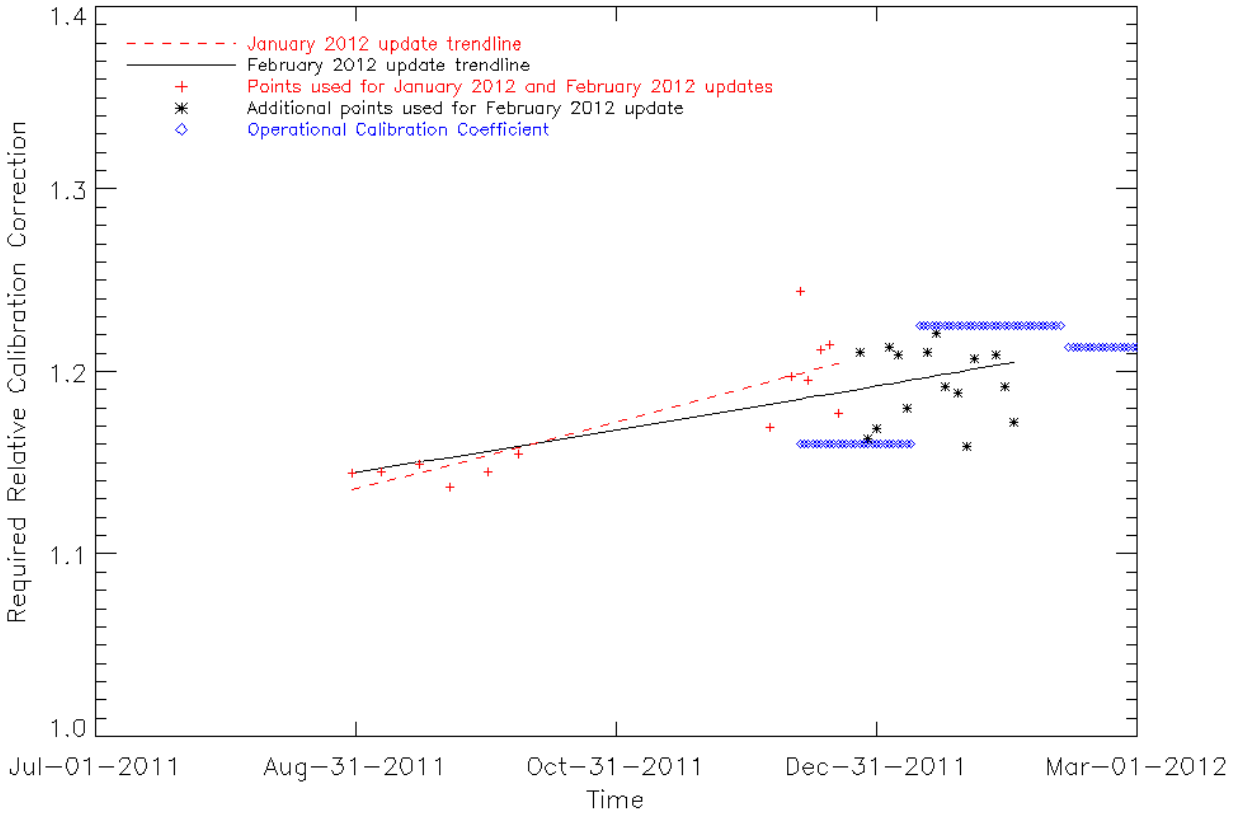

Figure 1. GOES-15 Imager Visible Channel Operational Calibration data, trend lines for the January 2012 (red dashed line) and February 2012 (black solid line) updates, and Operational Coefficients for December, January, and February (blue diamonds). The trendline for the January 2012 update was generated from the red '+' points, and the February 2012 update trendline was generated from the red '+' and black '*' points. The final set of operational coefficient values represent the February update as calculated – prior to any correction to the coefficient that would change the value to be equal to that of the January update.

Conclusion

With the understanding that decreasing coefficient anomalies in the GOES Imager Visible Channel Operational Calibration may occur for GOES-15, it is reasonable to develop a strategy to manage them. Three options were considered:

1) Publish the decreased Operational Calibration coefficient. This could cause confusion for those GOES users who are not familiar with the manner in which the coefficients are generated, as the decreased coefficient might be interpreted as a reversal in degradation.
2) Use the **regression-derived exponential function, or degradation rate** from the previous month until a monthly update yields a new exponential function with an

increased coefficient. There is a potential problem with this approach. If one month's update creates a regression-derived exponential function with an erroneously high degradation rate, then that function will yield rapidly-increasing calibration coefficients in future months. Updates to the regression with more realistic degradation rates will result in calibration coefficients that are always smaller than those of the erroneous function. Thus, the algorithm could "get stuck" with one particular month's update and not incorporate any further data points. In fact, long-term data suggest a "decreasing degradation", so this scenario might be probable, not just possible.

3) Publish the last month's **coefficient** until the Operational Calibration algorithm yields a larger coefficient. This prevents GOES users from being confused by a "reverse in degradation", but in a manner whereby future data will eventually be incorporated. Also, it is expected that using the previous month's coefficient will still provide a result within the estimated uncertainty. It is proposed to use this strategy. It should be mentioned that the regression parameters are published on the GOES Imager Visible Channel Operational Calibration website, and for those months where a decreased coefficient has been replaced with the previous month's, the regression parameters will not correspond to the calibration coefficient. These situations can easily be flagged, however, and this scenario is still considered the most favorable of the three.

Appendix

The decreasing calibration coefficient anomaly is not limited to GOES-15, and has occurred on three occasions for GOES-13 during its early operational period, as is shown in Figure 2. Considering this, observe Figure 3, where the Operational Calibration data and trendline have been plotted for the early operational period of GOES-13 and 15. The error bars for both satellites were calculated from the first 50 days of data. If there were calibration anomalies with GOES-13, then it should not be surprising that GOES-15, with an even higher level of uncertainty, exhibits them as well.

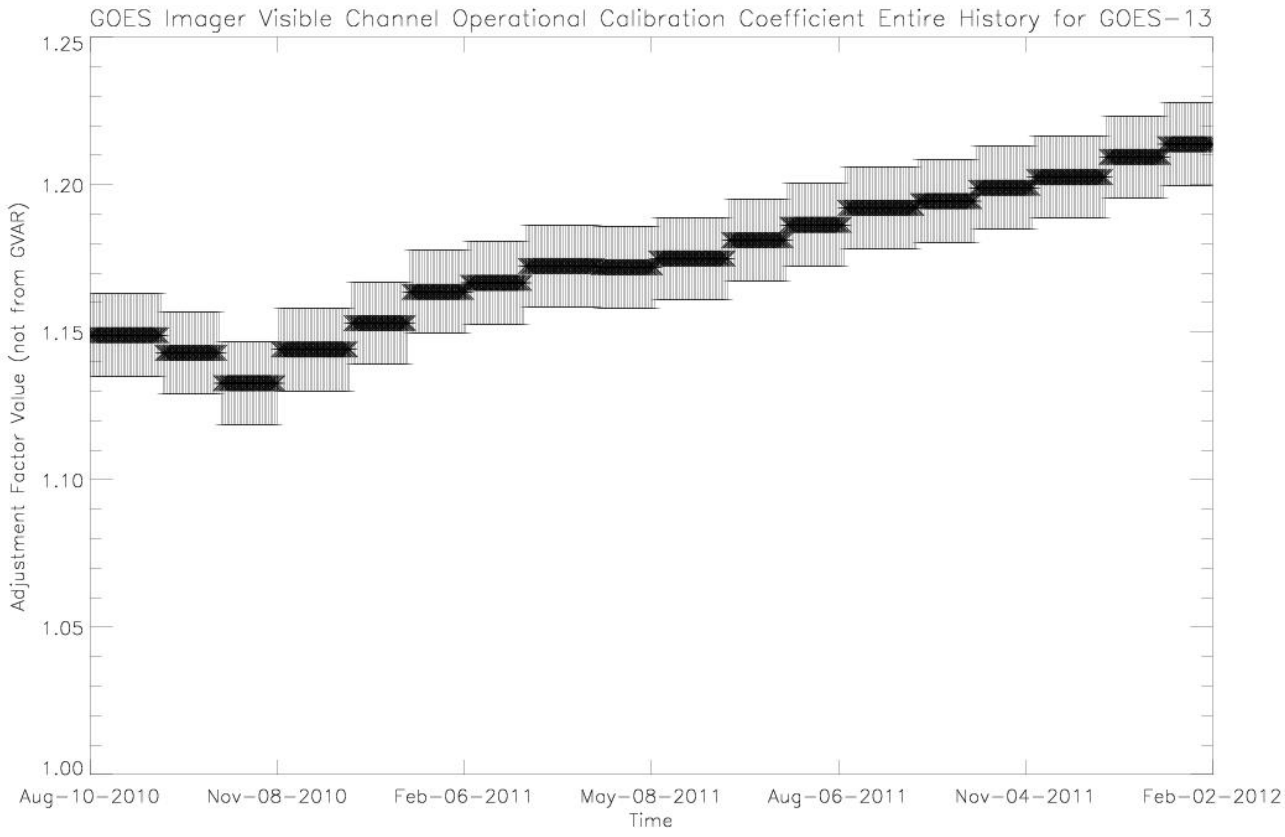

Figure 2. Entire history of GOES Imager Visible Channel Operational Calibration Coefficient for GOES-13 with error bars calculated from the current (as of Feb. 2, 2012) sigma value.

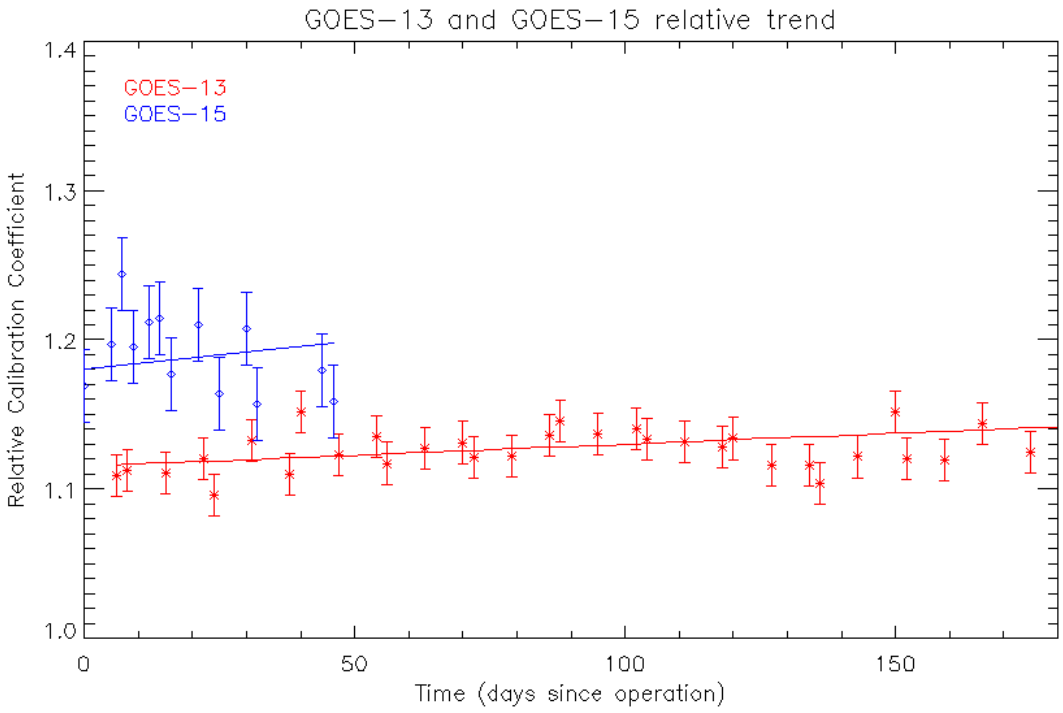

Figure 3. GOES Imager Visible Channel Operational Calibration data and trendline for GOES-13 and 15 during their early operational periods. The error bars shown for both satellites were calculated using data from the first 50 days.

The difference in estimated calibration uncertainty between the visible channel of the GOES-13 and GOES-15 Imager is not due to performance, but rather their operational position. GOES-13 operates as GOES-East at 75 degrees West longitude, and GOES-15 as GOES-West at 135 degrees longitude. Figure 4 shows the early operational period data for GOES-11 and 15, the two most recent GOES-West satellites, and Figure 5 shows the data from the two most recent GOES-East satellites, GOES-12 and 13. There is an obvious difference in estimated calibration uncertainty between the two, with a much smaller level for the GOES-East satellites. This is because the Operational Calibration algorithm uses high reflectance clouds, and there is a seasonal variation in the number of such clouds for GOES-West. This causes, on average, fewer co-located pixels per correction factor (per data point) for GOES-West satellites. For example, the average number of samples per GOES-11 data point was 196712; for GOES-12 the average number was 260550. This results in noisier data for GOES-West.

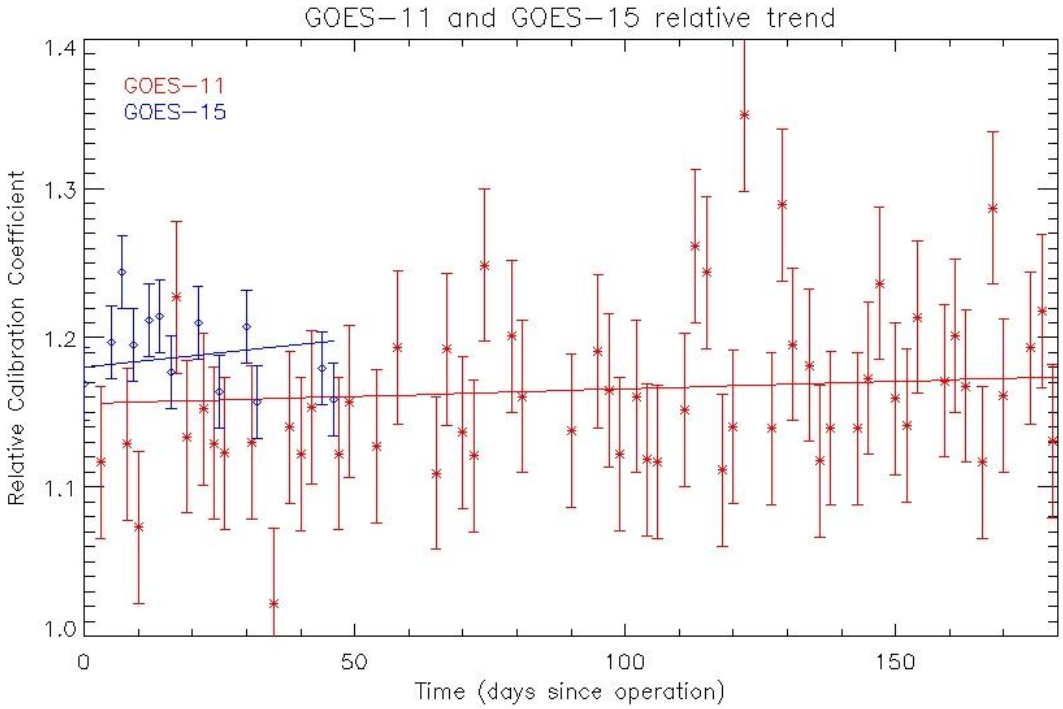

Figure 4. GOES-11 and GOES-15 Imager Visible Channel Operational Calibration data and trendline from their early operational periods. Both satellites operated as GOES-West. The errors bars shown were calculated using all available data, even data beyond the period shown in the plot in the case of GOES-11.

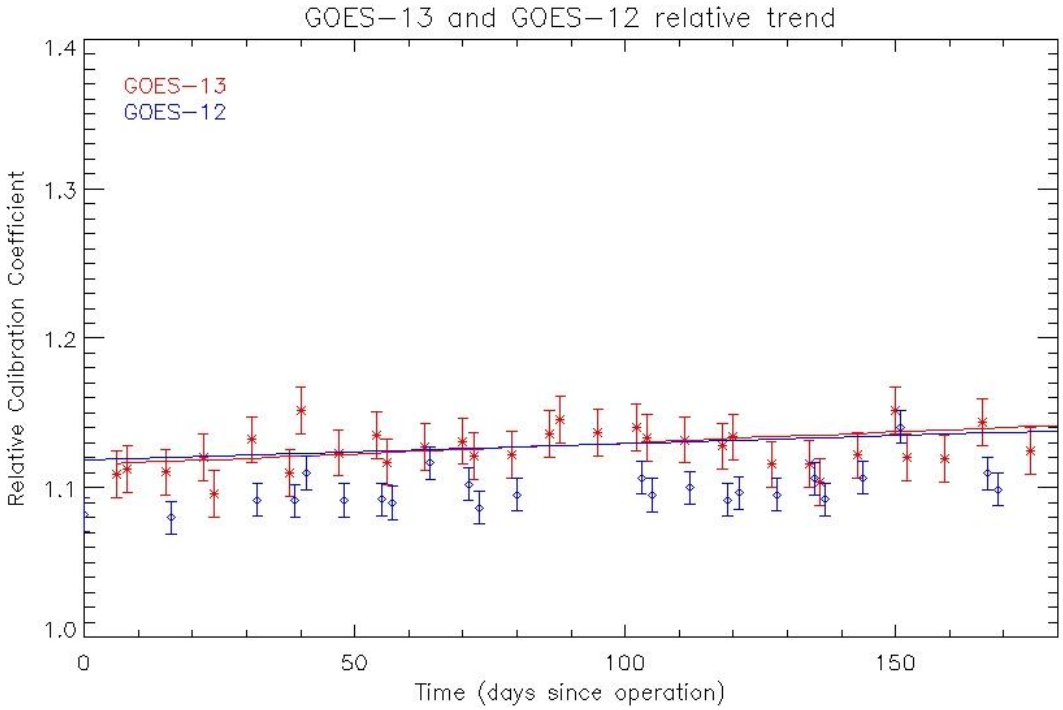

Figure 5. GOES-13 and GOES-12 Imager Visible Channel Operational Calibration data and trendline from their early operational periods. Both satellites operated as GOES-East. The errors bars shown were calculated using those data shown in the plot.

Looking further at Figure 4, the early GOES-15 data have exhibited a smaller estimated calibration uncertainty than GOES-11, though they are both GOES-West satellites. This is despite the fact that the GOES-11 uncertainty was calculated using many more data points than with GOES-15. The reason for the discrepancy is the difference in the spectral response between the two. The GOES-15 Imager visible channel has a narrower spectral response and therefore a spectral response that is more similar to that of MODIS. Since MODIS data are used as truth for the Operation Calibration, this means that the spectral correction has less error, resulting in smaller overall uncertainty.

Works Cited

Wu, X., & Sun, F. (2005). Post-launch calibration of GOES Imager visible channel using MODIS . *SPIE Earth Observing Systems X*.